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OPERATIONS DIVISION

SLUG RUPTURES IN THE OAK RIDGE NATIONAL LABORATORY PILE

By

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OPERATIONS DIVISION

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C. D. Cagle
L. B. Emlet

DATE ISSUED

OCT 13 1948

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SLUG RUPTURES IN THE OAK RIDGE NATIONAL LABORATORY PILE

September 28, 1948

Since the start of pile operation in November, 1943, there have been forty-eight known slug failures with a total of sixty-seven slugs being involved. These figures do not include the rupture of a $Th_2(CO_3)_3$ can nor a uranium donut. Neither do they include five to seven empty aluminum cans found in the canal during 1946. The sixty-seven slugs contained approximately one hundred seventy pounds of uranium of which an estimated sixty pounds disappeared as the oxide while the remainder was recovered as metal cores. By far the greatest proportion of the oxide fell into the canal, but some of it entered the cooling-air exhaust system. There is no way to determine the amount which was carried through the stack into the atmosphere; however, this should be small in comparison to the quantity lost because the exhaust fan housings and the exit ducts from the fans to the stack are oil-coated inside and tend to pick up a large amount of whatever particles may be in the air stream. In addition, the exit duct provides a tortuous path for the exhaust air having about seven right angle bends.

In view of the number of slugs that have been charged into the pile compared to the number that have failed, the efficiency of the tests run on the slugs before their use was extremely high. As of August 31, 1948, a total of 163,661 slugs had been charged into the pile. This includes the 40, 639 slugs now in the pile. Of this number forty-eight or 0.03% had failed. If the total sixty-seven slugs involved (including secondary ruptures) be considered, this would raise the percentage of failures to only 0.04%. This efficiency in testing methods cannot be easily improved. (See Appendix II.)

This report is intended to present as thorough a collection of data having a suspected bearing on the causes of slug failures as is possible from the records that have been kept and to correlate to some extent those factors seeming to have the greatest influence.

Causes of Ruptures

A study of the collected data makes it apparent that, given a full pile loading of new slugs at one time, the ruptures that might happen as time passes would begin in the center rows of the pile and occur thence toward the perimeter. Since only the nautron flux and the temperature of the pile are distributed in this manner, it is fair to assume that one or both of these influence the cause or causes of the ruptures. Unfortunately, the positions of the ruptured slugs in the slug rows were recorded for only twenty-two of the forty-eight rows having slug failures; however, from these twenty-two cases (assuming them to be a random selection) the following important distribution can be made:

Slug ruptures east of centerline- 5
Slug ruptures west of centerline- 17
(See graph, Figure 5.)

These extend in an eastward direction from center only a distance of seven slugs or twenty-eight inches but extend in a westward direction a distance of eighteen slugs or seventy-two inches. It should be noticed that those ruptures occurring east of the center were in central rows -- those having highest temperatures. Thus, with respect to pile conditions, it may be concluded that temperature has the greatest influence on the slug ruptures since only the temperature distribution follows the rupture distribution in this direction. The neutron flux distribution is symmetric in the east-west direction. (See Figures 1, 2, 2a, 3, and 4.)

There are three known reasons why the temperature should influence rupturing:

1. If a tiny hole is already in the slug jacket when it is charged into the pile, it is inevitable that the slug will develop into a rupture if it is in a temperature zone which is high enough to enhance oxidation. Report BR-223, May 13, 1943, shows that uranium oxidizes twenty-seven times faster at 250° C. than at 100° C. (See Figure 6.). This indicates that two slugs that have an equal chance of rupturing due to tiny holes in their jackets would rupture at different times in different temperature zones. Thus, if one were placed in a 250° C. zone and ruptured after fifty days, the other slug in a 100° C. zone would not rupture until after 1,350 days. This affords one explanation of the present rupturing of some of the slugs that have been in the lower temperature zones of the pile for the past three or four years.

   Another factor to be considered in this respect is the effect of thermal cycling or the breathing action through a hole when the slug is alternately heated and cooled during start-ups and shutdowns. The greater the temperature differential, the greater the volume of air drawn into the slug. For this reason, it is thought that excessive shutdowns will increase the rate of rupturing. Since the greatest temperature differential is experienced in the centrally-located rows and particularly west of the center line, the recycling may partially account for the distribution of ruptured slugs. (See Appendix II.) Based upon the number of slugs that were rejected by the Modified Bubble Test after having been passed by the Weight (Borst) Test, about 0.5% of the 32,202 weight-tested slugs which are in the pile are subject to failure. This would give a total of one hundred sixty-one or more ruptures yet to be expected among the older slugs in the pile. This does not consider the possible failures of imperfect slugs that may have been passed by the Modified Bubble Test which reportedly detects holes as small as 10^{-6} inches in radius. There are 8,437 of these slugs now in the pile.

2. If a burr caused by machining were left on the uranium slug when it was jacketed, the repeated expanding and contracting of the aluminum jacket caused by temperature changes due to start-ups and shutdowns of the pile may cause a hole to be worn through the jacket by the burr, allowing the uranium to oxidize and cause rupturing.

3. At temperatures above 350° C. the aluminum jacket begins to alloy appreciably with the uranium. This may make the jacket brittle enough to cause rupture. It is believed that only secondary rupture can be attributed to this effect, i.e., those that occur in the slug row after one slug has ruptured enough to seal off the flow of cooling air. When such a

condition develops, temperatures greater than 400° C. may be expected. One row of eleven slugs has been operated in the pile for five months now with no failure. This is a test being run by the Physics Division to determine the effects of the alloying of the uranium with the aluminum jackets.

Effects of Ruptures on the Pile

The effect of the first thirty-two slug ruptures was a very gradual build-up of activity on the cooling-air exhaust system, particularly in the oil-soaked fan housings and ducts. This was not alarming since the active particles caught in these places were washed into the waste disposal system each time the fans were decontaminated prior to a bearing change. The probe, an oil-soaked rag suspended in the exit air stream (See Appendix III.), showed a background change of only five mr/hour over a period of four years (See Figure 7.). The low amount of the uranium oxide reaching the exhaust system was due to the great care exercised in discharging the ruptured slug. The rows were pushed gently with the cooling air flow reduced and the ruptured slug caught in a small pail and lowered gently to the mattress plates where it was loosed to fall immediately into the water in the canal.

The thirty-third slug failure was detected November 30, 1947, and located in Channel 2079. Nine days were required to clean the channel using prods, assorted core drills, and chisels. It was impossible in this case to use the usual care to keep the oxide from getting into the exhaust system. The bridge tube (a 3' section of $1\frac{1}{4}$" std. iron pipe bridging the inlet plenum chamber to allow passage of slugs) had to be removed so that some slugs could be pulled into the inlet plenum chamber. Some of the oxide was carried into other channels by the air stream. Altogether thirteen slugs or about thirty-two pounds of uranium disappeared as oxide. Most of this material fell into the canal and the bottom of the inlet air plenum chamber, but enough collected along the walls of the exit air duct to cause the normal probe reading to rise from four to five mr/hour to twenty to thirty mr/hour since that time (see Figures 8, 9, and 10). Just after the pile was restarted, the probe readings increased very rapidly making it necessary to renew the probe as often as three times per day. This made the probe useless as an indicator of a rupture in an early stage. More than a month elapsed before any stability was reached. During this time the constant air monitor located between the pile and the fans could not be used because of the great amount of contamination in the duct. Also the scanning machine gave erroneous readings. For these reasons a visual inspection method of scanning was adopted as a monthly routine. The majority of the ruptured slugs since that time have been located by this method. (See Appendix IV.)

It is interesting to note that after the extremely serious slug rupture of November 30, 1947, a memorandum from C. H. Perry to K. Z. Morgan on December 11, 1947, indicates that no air contamination existed nor could any of the radiation survey results be correlated with the events in the pile.

The detection and location of slug failures thirty-four through forty-nine were more or less uneventful except for the decided progress of the rupturing before discovery due to lack of sensitivity of the detection devices. Several of the jackets had swollen to such a size that considerable force had to be used to expel them from the channels. Slug failure number fifty (the forty-eighth X slug) which was detected on August 30, 1948, by probe readings was located in Channel 1069. The force applied in trying to push the row with a push-rod caused good slugs to become wedged among those that had oxidized. The resulting jam had to be picked apart with prods, chisels, and crude core drills requiring a shutdown of three days. Fortunately, Hole 43, which is almost directly behind Channel 1069, gave access to the rear of the channel so that it was not necessary to remove the bridge tube or to pull any material into the inlet plenum chamber. Of the forty-seven slugs in the channel three disappeared as oxide and two more had ruptured and were partially oxidized. It is estimated that twelve pounds of uranium as the oxide were dispersed into the canal and the air exhaust system.

With no filtering system in the exhaust duct it was unavoidable that some radioactive particles escape the stack. The pile can therefore be assumed to be one of the prime contributors to the particle situation now being investigated.

Suggested Changes to Prevent Ruptures

A program is now under way to build a filtering system into the exhaust air system to stop the escape of radioactive particles from the stack. This will end the dangers from a widespread biological standpoint, but ruptures will continue to occur in the pile causing loss of operating time, exposure of operating personnel, and may lead to great danger to the pile itself. The two slug channels from which rupture jams had to be drilled and prodded loose were so damaged that they have not been recharged. Measures should therefore be taken to make possible the detection of the failures at a very early stage or to end the danger of rupture altogether. Two methods of early detection are now being investigated. These are both based on the restriction of cooling air by a swelling slug. One is the direct measure of the air flow change and the other is to measure the resulting temperature change. The changes that have been suggested to prevent ruptures are:

1. The use of uranium oxide as a slug material instead of the metal. This would require that the uranium be enriched in the 235 isotope. If such a scheme were used, it would be extremely unlikely that rupture would occur under any normal pile condition even if a small air leak were in the jacket.

2. Use of double jackets on the slugs. The advantages of such an arrangement are obvious.

3. Adoption of a helium system similar to that of the Brookhaven National Laboratory.

L. B. Emlet

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ORNL-170
September 28, 1948

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APPENDIX I

RUPTURED SLUG DATA

Slug No.	Row No.	Date Charged	Date Ruptured	Total Age (Days)	Acc. KWH	Position in Row	Zone	Temperature	Radial Coordinate
1	1764	7-5-44	9-27-44	84	4,565,153	--	2	200-250	14
2	1264	7-20-44	10-10-44	83	4,749,688	--	5	190-240	26
3	1564	10-5-44	10-31-44	26	1,919,878	#12	3	200-250	18
4	2165	10-5-44	12-28-44	84	6,141,909	#22	2	200-250	14
5	2071	10-20-44	4-8-45	169	11,762,378	#23	1	200-250	9
6	1770	10-27-44	4-18-45	173	12,096,595	#23	1	200-250	4
7	2269	10-5-44	4-23-45	200	14,064,486	--	1	200-250	12
8	2373	9-13-44	4-24-45	223	15,423,544	--	4	200-250	24
9	1865	10-8-44	5-4-45	238	14,637,977	#15	1	200-250	11
10	1563	10-8-44	5-25-45	259	16,312,052	#13	3	200-250	22
11	1969	10-5-44	6-20-45	258	18,339,151	--	1	200-250	2
12	1772	10-20-44	7-9-45	261	18,742,706	#7	1	200-250	11
13	1465	?(19 on 2-27-45)	8-6-45	160	11,859,038 from 2/27/45	--	3	200-250	17

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APPENDIX I

Slug No.	Row No.	Date Charged	Date Ruptured	Total Age (Days)	Acc. KWH	Position in Row	Zone	Temperature	Radial Coordinate
14	1865	5-4-45	9-5-45	124	9,845,067	#5	1	200-250	11
15	1764	9-27-44	9-10-45	348	25,549,214	--	2	200-250	14
16	1773	8-14-45	11-13-45	91	7,588,165	#23	2	200-250	14
17*	1867	5-5-44	12-19-45 (Doughnuts)	593	40,382,093	--	1	200-250	1
18	2471	11-3-44	12-31-45	423	32,490,510	#5	4	200-250	23
19	1663	9-26-44	3-22-46	542	42,512,509	#7	3	200-250	20
20	1366	10-27-44	3-24-46	513	40,762,898	--	3	200-250	19
21	1264	10-10-44	5-4-46	570	45,680,090	--	5	190-240	26
22*	1858		5-14-46 (Myrnalloy)	392		--	7	90-190	38
23	1266	12-12-44	5-17-46	521	42,279,392	#5	4	200-250	23
24	2165	12-28-44	5-20-46	508	41,218,049	#18	2	200-250	14
25	1576	10-7-44	2-4-47	850	68,092,489	--	5	190-240	28
26	1366	3-25-46	2-6-47	319	26,044,865	#19	3	200-250	19
27	1565	4-15-47	4-26-47	11	940,978	#13 or 14	2	200-250	14
28	2368	6-12-47	8-20-47	69	5,646,906	--	2	200-250	16
29	1862	10-5-44	10-17-47	1107	89,592,310	--	4	200-250	22

* Not included as a rupture in preceeding discussion.

[redacted]

APPENDIX I

[redacted]

Slug No.	Row No.	Date Charged	Date Ruptured	Total Age (Days)	Acc. KWH	Position in Row	Zone	Temperature	Radial Coordinate
30	2165	6-12-47	10-31-47	141	11,538,902	--	2	200-250	14
31	1061	8-2-44	11-5-47	1190	94,684,096	--	7	90-190	39
32	2574	9-8-44	11-12-47	1160	93,329,520	--	6	150-190	31
33	2079	9-26-44	11-30-47	1160	93,730,533	--	7	90-190	39
34	2074	10-27-44	12-20-47	1149	92,349,731	#17	3	200-250	20
35	2568	11-3-44	12-21-47	1143	91,941,112	--	4	200-250	25
36	1881	11-6-44	12-23-47	1142	91,962,945	--	7	90-190	46
37	2460	9-8-44	12-26-47	1204	96,011,021	--	7	90-190	37
38	1871	11-18-47	1-23-48	68	4,308,412	--	1	200-250	6
39	1669	11-16-47	1-27-48	72	4,814,178	#2	1	200-250	5
40	2165	10-31-47	3-14-48	135	10,093,938	#13	2	200-250	14
41	2170	1-13-48	5-2-48	110	9,265,047	#12	1	200-250	10
42	1159	8-5-44	5-9-48	1374	108,977,026	--	7	90-190	43
43	1077	10-27-44	7-20-48	1362	107,841,673	#16	7	90-190	43
44	0961	9-26-44	7-27-48	1400	112,523,176	#16	7	90-190	43

[redacted]

APPENDIX I

[redacted]

Slug No.	Row No.	Date Charged	Date Ruptured	Total Age (Days)	Acc. KWH	Position in Row	Zone	Temperature	Radial Coordinate
45	1668	3-6-48	7-28-48	144	11,998,307	#25	1	200-250	5
46	1459	9-8-44	7-29-48	1420	113,762,808	--	7	90-190	37
47	2874	10-21-44	7-30-48	1378	111,112,634	--	7	90-190	42
48	2879	5-20-44	7-30-48	1532	118,791,188	--	7	90-190	59
49	2678	11-3-44	8-3-48	1369	110,537,494	--	7	90-190	46
50	1069	10-31-44	8-31-48	1404	113,270,566	--	5	190-240	28

[redacted]

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September 28, 1948

APPENDIX II

SLUG TESTING PROCEDURES AND RESULTS

I. SLUG DESCRIPTION

The uranium metal is received as 2S aluminum-jacketed slugs about 1.1" in diameter and 4" long. The urnaium cylinders are machined to a tolerance of 1.100" $\pm$ 0.002" diameter and 4.000" $\pm$ 0.010" long. The chamfer on the base end of the cylinder has a radius of 0.010". A groove runs longitudinally on the cylinder 0.017" to 0.025" wide and 0.015" to 0.20" deep.

This machined uranium cylinder is jacketed in a 2S aluminum can. To date two types of aluminum casings have been used.

1. A resistance-welded jacket having 0.017" to 0.020" side walls with a total weight of fourteen grams.
2. An arc-welded jacket having 0.035" side walls with a total weight of 24.5 grams. (This type is now in pile.)

The aluminum cans are 4.375" long and 1.116" inside diameter. After the uranium cylinder is placed in the can, the assembly is forced through a die of such diameter to draw the aluminum tight around the uranium. A circular cap, 1.102" diameter and 0.060" thick, is inserted and the extra metal trimmed. The closure is completed by electrically welding the seam. The first slugs used (1943-44) were prepared by resistance welding while all others (1944 to present) have been arc-welded.

II. SLUG SUPPLIERS

In general, three shipments of slugs have been received as follows:

1. Approximately 100 tons of resistance-welded slugs all of which were used or returned for reworking by the middle of 1944. These slugs were prepared by several manufacturers.

2. Approximately 130 tons of arc-welded slugs all of which have been loaded into the pile. These slugs were prepared by several venders.

3. Approximately 40 tons of arc-welded slugs which were prepared by the Hanford Engineer Works. Some of these slugs have been loaded into the pile while the others are in storage.

III. SLUG TESTING PROCEDURES AND RESULTS

Several different methods have been used to determine if the aluminum jackets leaked.

1. <u>Hydrogen Test:</u>

(a) <u>Procedure</u>

It is known that hydrogen reacts rapidly with the metal at elevated temperatures. Therefore, if the slugs were heated in an atmosphere of hydrogen the reaction of the hydrogen with the metal of a slug would increase the volume within the jacket and cause bulging and splitting. Visual examination of the slug after the test would indicate those slugs with the leaking jackets.

The procedure for this test was developed during the first three weeks of the large scale testing operation. The slug-loaded trays were placed into a large, perforated container and lowered into the furnace which was heated

[redacted]

to 300° C. in an atmosphere of air. The furnace retort was then evacuated to a pressure of approximately 3 in. of mercury. After holding this vacuum for thirty minutes, hydrogen was introduced until the internal pressure exceeded atmospheric pressure by approximately one-half pound. This pressure was maintained by a small flow of hydrogen through the ten-hour heating period at 300° C. $\pm$ 25° C. On completion of this heating period the retort was purged to remove the hydrogen. The charge was then removed from the furnace, allowed to cool, and inspected.

During inspection the slugs were separated into four groups.

(1) Distortions and ruptures resulting from hydride formation.

(2) Distortions apparently caused by gas pressure generated inside the jacket.

(3) Scars and scratches caused by mishandling in shipping, testing, etc.

(4) Accepted slugs.

(b) Results

Approximately sixty-five to seventy tons of metal slugs were tested by this method. The slugs that had passed the test were examined in spot checks to determine whether they were showing signs of failure after their initial test and examination. Results of these tests indicated that the slugs could not stand a ten-hour hydrogen treatment at 300° C. without partial hydride formation between the slug and its aluminum jacket. Small amounts of hydrogen appeared to diffuse through the thin, aluminum jacket, even though there

[redacted]

was no leak in the jacket nor in the weld. As a result, hydrogen testing was abandoned about September 1, 1943, and all slugs tested by this method were retested by the deflection method.

2. Deflection Test:

(a) Procedure

On September 26, 1943, the first testing of slugs by the deflection method began. This test was made to determine which of the slugs had leaks in the capped and welded end of their aluminum jackets. Briefly, the test was made by subjecting the weld on the jacket to 175 pounds per square inch of nitrogen pressure after exposing the slugs to a temperature of 300° C. for one hour. The purpose of the furnace heating was to exert thermal tension on the weld to show up a leak. If there was a leak in the jacket, the nitrogen would enter the jacket causing it to swell. This swelling was then checked with a micro-gauge deflection instrument which measures the distortion of the bottom of the jacket to within 0.001 of an inch. All of the slugs that were subjected to the test were segregated according to whether they showed zero deflection, a deflection of one to five mils, or a deflection greater than five mils. Those showing zero deflection were accepted slugs; those with a deflection of one to five mils had slow leaks; while those with a deflection greater than five mils were rejected.

(b) Results

Of 74,000 slugs tested, 54.0% were found to be zeros. Approximately 5,000 of the zeros found in the original test were retested and only 87.8% were found to have remained in the "zero" class. Then 1,400 of the retested zeros were again tested and only 88.0% of these were found to still be zeros. This indicated that due to handling, packing, stacking, etc., approximately 12.0% rejects could be found in any previously accepted material. The results of the deflection test could not be reproduced with certainty for any one slug, probably because the jacket stretched due to the pressure during the initial test and did not stretch as much on subsequent tests.

3. Bubble Test:

(a) Procedure

During September of 1943 the Bubble Machine was devised for testing slugs also. The plan was to expose slugs which were placed in a compression chamber to a nitrogen gas pressure of 175 pounds per square inch and then to submerge these slugs in kerosene to determine whether or not any bubbles arose from the slugs. The principle employed was that nitrogen at 175 pounds per square inch would enter any leaks in the jackets. Then with the slugs under kerosene and the nitrogen pressure released, the nitrogen would leave the jacket and bubble up through the kerosene.

Many difficulties were encountered during the experimental runs. As the nitrogen pressure was released from the chamber, a mist was formed which impaired vision. The bubbles could not

[redacted]

be seen for quite a while after the pressure has been released.

(b) Results

Slugs that had been passed by this bubble-test apparatus were found to have leaks using the deflection-test method. This method was discarded and testing work continued using the deflection method.

NOTE: All of the above tested slugs were of the resistance-welded type. They were loaded into the pile for the initial start-up and completely replaced by about July, 1944, with arc-welded slugs which had been tested by the Weight (Borst) Test.

4. Weight (Borst) Test: (See Report CP-1430)

(a) Procedure

This test is based on the knowledge that the metal reacts rapidly with the oxygen of the air at elevated temperatures. Therefore, a slug with a leak in the jacket would gain weight due to the reaction of the metal with the oxygen. Weighing the slug before and after a heating would reflect any change in weight.

A charge of slugs was given an initial heating period of twenty-four hours at 290° C. $\pm$ 10° C. in an oven to remove any volatile matter adhering to the jackets. After cooling, each slug was given an initial weighing to a tenth of a milligram and then placed back in the over for a ten-day heating period at 290° C. $\pm$ 10° C.

On completion of this heating period the slugs were re-weighed to a tenth of a milligram and classified as accepted, retested, or rejected material. A statistical method of accepting and rejecting the slugs was developed to compensate

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for the inaccuracies of the balances and errors made by the operators. The accepted slugs were then stored in the vault for pile use. Retest slugs were stored until enough accumulated to provide for a retest charge which were tested in the same manner as new material. Rejected slugs were stripped and returned for rejacketing. Theoretically, holes as small as 10^{-6} inches in radius can be detected by this method.

(b) Results

The testing of slugs by the weighing method was completed on February 10, 1945, with the following results:

Number of slugs tested	104,058	
Number of slugs accepted	100,118	96.21%
Number of slugs rejected	3,940	3.79%.

The cause for the rejection of the 3,940 slugs was broken down as follows:

Jackets swollen or burst by oxide formation	1,255	31.9%
Jackets swollen by gas formation	611	15.5%
Excessive gain in weight	481	12.2%
Pitted, scarred & concave jackets	547	13.8%
Rejection by visual inspection of weld	1,046	26.6%.

5. Modified Pressure Bubble Test:

(a) Procedure

This method for the testing of slugs originated at Argonne National Laboratory and was further developed at Oak Ridge National Laboratory. The slugs, after a visual inspection, are heated to 300° C. $\pm$ 10° C. for a period of five days. Upon removal from the oven any that show signs of swelling or rupture are discarded. All of the

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others are loaded into an autoclave with the welded end up. The slugs are exposed to 300 pounds per square inch helium pressure for sixteen to eighteen hours. Immediately after the release of the helium pressure, the slugs are placed end up under acetone and the end covered with a gas collector. After remaining under the acetone for five hours, all slugs which show the release of gas bubbles are rejected. Holes as small as 10^{-6} to 10^{-7} inches in radius should be detected by this method.

(b) Results

Slugs tested	33,629	
Slugs accepted	33,176	98.65%
Slugs rejected	453	1.35%.

The cause for the rejection of the 453 slugs can be broken down as follows:

Jackets swollen or ruptured by gas or oxide formation during heating period	217	47.9%
Pitted or scarred jackets	25	5.5%
Slugs leaking gas	211	46.6%.

Upon completion of the above tests on the Hanford-prepared slugs approximately 7,000 slugs that had originally passed the Weight Test were retested by this method with the following results:

Number of slugs tested	5,120	
Number of slugs accepted	5,094	99.49%
Number of slugs rejected	26	0.51%.

The twenty-six unaccepted slugs were rejected because of leaking gas from the jackets and not because of swelling during heating or due to scarred jackets.

[redacted]

[redacted]

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2. Final Report of Slug Testing in the 100 Area

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4. Procedure for Accepting and Rejecting Slugs in the 100 Test Area

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9. Testing of 40 Tons of X Slugs to be Shipped from Hanford

   S. E. Beall to M. C. Leverett, 7/31/46

10. Testing of 40 Tons of X Slugs from Hanford by the Modified Pressure Bubble Test

    J. D. Knox to L. B. Emlet, 7/28/47

11. Notes of L. B. Emlet.

[redacted]

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APPENDIX III

METHODS OF DETECTING PRESENCE OF A RUPTURE

The Probe

In the past the best indication that a ruptured slug was in the pile was the contamination picked up by an oil-soaked rag suspended in the exit air duct between the pile and the exhaust fans. Until after 1944 the probe seldom read more than one or two mr/hour except in the event of a rupture. (When no rupture exists, the probe reading always reaches a more or less constant value due to an equilibrium being established between the number of particles impinging upon it and the number being blown off.) Up until the end of November, 1947, a probe reading of ten mr/hour obtained within one hour after inserting a clean probe was a positive and infallible indication of a ruptured slug. (See Figure 7.)

After the rupture of the thirteen slugs in Channel 2079 which was detected November 30, 1947, so much radioactive uranium oxide dust had collected in surrounding slug channels and along the floors and walls of the exhaust duct that the constant reading of the probe rose to between fifteen and twenty-five mr/hour. Also many times the probe reading has risen suddenly to as much as seventy mr/hour when no rupture existed but only a release of some pocket of the uranium oxide already in the duct. Therefore, the probe is no longer a positive indicator of a rupture. (See Figures 8, 9, and 10.)

Constant Exhaust Air Monitors

There are two monitoring instruments in the exhaust air system. One on the exhaust side of the fans is primarily intended to show any deviation in the radioactivity of the air gases themselves and not the activity of any

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particles since the air sample flow is so low that practically no particles enter the system. Those that do are lost in a precipitron before the sample reaches the ionization chamber. The other monitoring system takes its sample from the section of the duct between the pile and the fans and consists of a forty to fifty cfm pump that draws an air sample through a cloth filter adjacent to an ionization chamber. The filter collects any particles that come through the system. A recorder located at the control desk indicates any increase or decay of particles on the filter. This is an integrating device so the filter must be changed when it becomes excessively contaminated.

Before the November, 1947, rupture a slug failure was indicated when a very radioactive particle reached the filter giving a sudden rise in reading followed by a decay curve. Now, however, the filter becomes contaminated so rapidly that the instrument must be run on a less sensitive scale so that a rupture now is indicated by a sharper rise in the slow integrating curve. A slug must be rather well ruptured before this rise starts.

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ORNL-170
September 28, 1948

APPENDIX IV

METHODS OF LOCATING RUPTURED SLUGS

The Scanner

The pile scanner is an air sampler located atop the pile that takes its samples from the exit end of the metal channels, records their activity, and discharges them back into the pile. It consists of a long, telescoping sampler tube that can be lowered into the pile behind any desired channel, a length of one-inch rubber hose connecting the tube to a stationary ionization chamber, and a ten to fifteen cfm blower that pulls the sample through the svstem and discharges it into the pile exhaust air system. The pully arrangement for lowering the tube is supported on a wheeled frame that runs on rails alongside the row of scanning holes.

The function of the scanner is to locate the channel containing a ruptured slug after its presence has been detected by the probe and/or the exhaust air monitor. Those channels for which it records a high activity must now be checked visually by looking through them with the aid of a light suspended in the exhaust plenum chamber because the channels which have at some time contained ruptures and those in the immediate vicinity of 2079 still show higher than normal activity because of the uranium oxide dust still being given up from cracks in the graphite.

Visual Inspection

Since the rupture of the thirteen slugs in Channel 2079 and the following undependability of the probe and exhaust air monitor, the only method left to assure the detection of a slug rupture was routine visual inspection. Unfortunately, the routine was established on a monthly basis and failed to detect the rupture in Channel 1069 until August 31, 1948, after enough

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slugs had ruptured to produce a jam. It is felt that a visual inspection twice per week would have discovered the rupture in ample time to prevent the jam occurring.

Visual inspection consists simply of looking for any irregularities along the line of slugs in a channel with the aid of a light suspended in the exhaust air plenum chamber. A bulged or split slug can easily be seen. As a check, an air sample is taken from the hole by the scanner and, if it is higher than normal, the presence of a rupture is assured.

During an inspection of this sort, the operators must look into holes from which radiation beams of twenty-five to fifty mr/hour are emanating. Safety glasses are worn as beta shields for the eyes, but there is no way of shielding for gamma. Periscopes have been suggested for looking into the channels from the sides but since some 830 channels must be scanned, the time required to insert a periscope into each channel would be so time-consuming that it would not be feasible.

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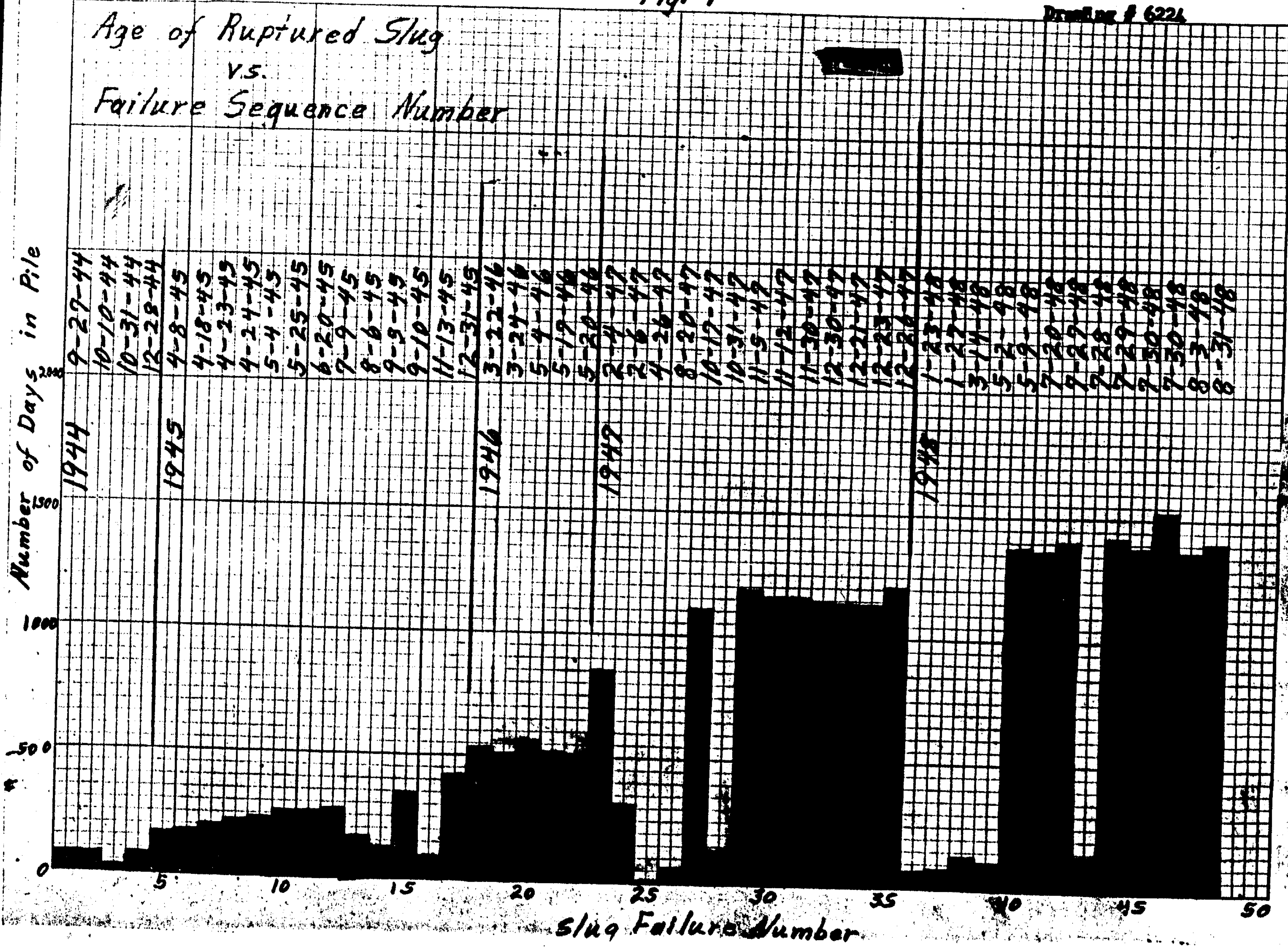
Fig. 1


Drawing # 6224
[redacted]
Age of Ruptured Slug
v.s.
Failure Sequence Number
Number of Days in Pile
0
500
1000
1500
2000
Slug Failure Number
5
10
15
20
25
30
35
40
45
50
1944
1945
1946
1947
1948
9-27-44
10-10-44
10-31-44
12-28-44
4-8-45
4-18-45
4-23-45
4-24-45
5-4-45
5-25-45
6-20-45
7-9-45
8-6-45
9-9-45
9-10-45
11-13-45
12-31-45
3-22-46
3-24-46
5-4-46
5-19-46
5-20-46
2-4-47
2-6-47
4-26-47
8-20-47
10-17-47
10-31-47
11-5-47
11-12-47
11-30-47
12-30-47
12-21-47
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1-23-48
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5-2-48
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8-3-48
8-31-48

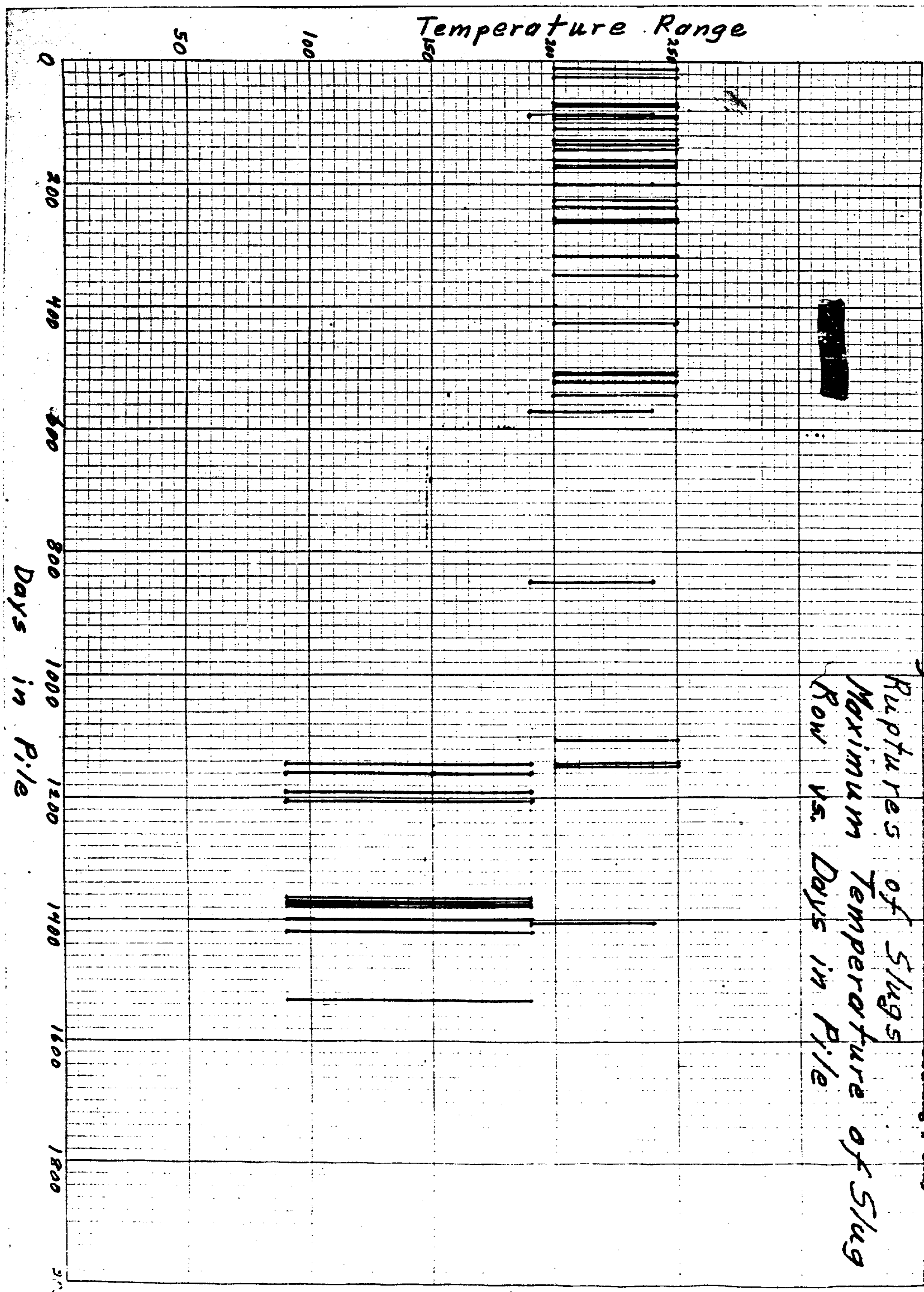

Fig. 2
Ruptures of Slugs
Maximum Temperature of Slug Row vs. Days in Pile

Drawing # 6225

[redacted]

Fig. 2-a

Drawing # 6226

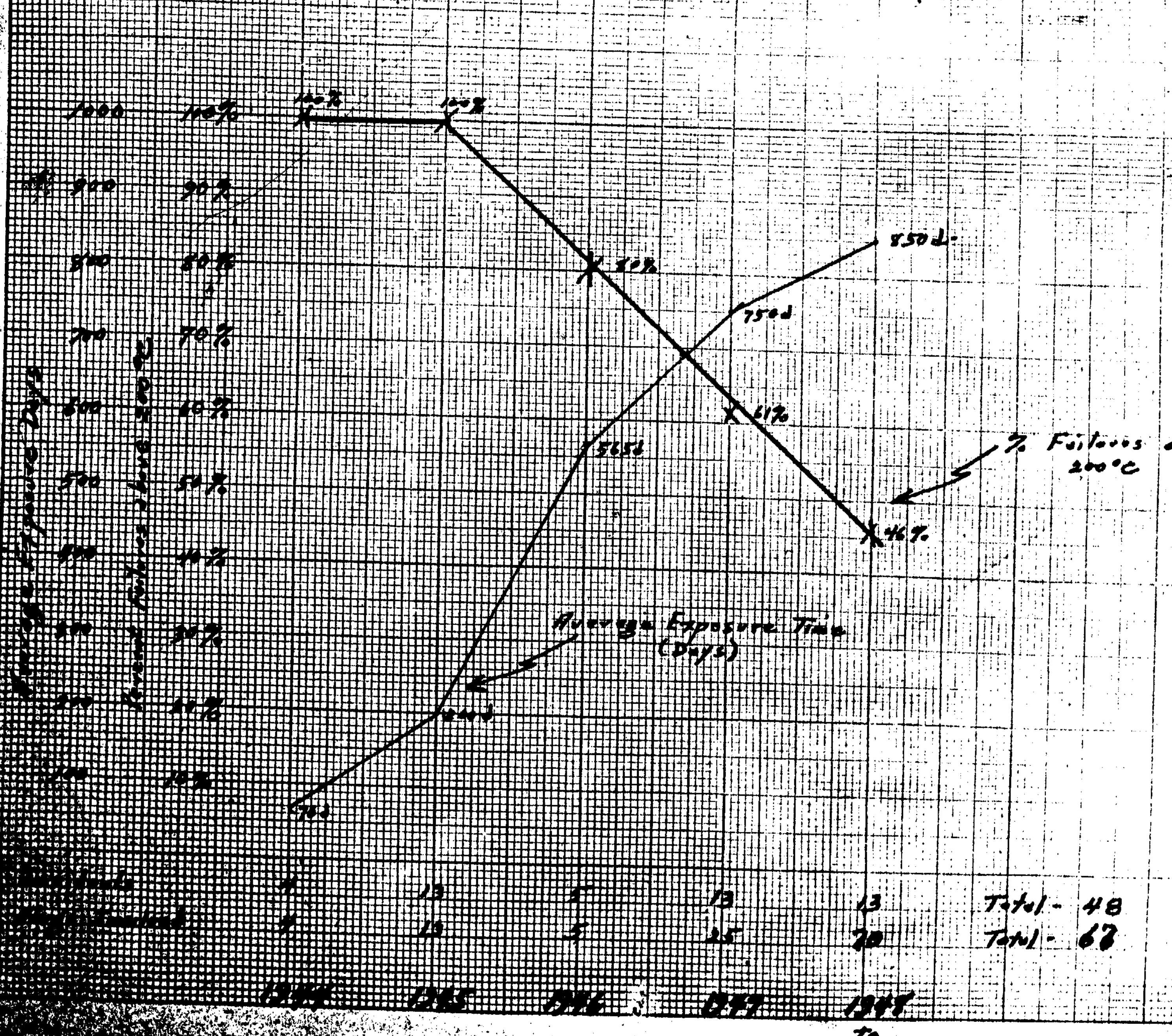

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Fig. 2-A

SECRET

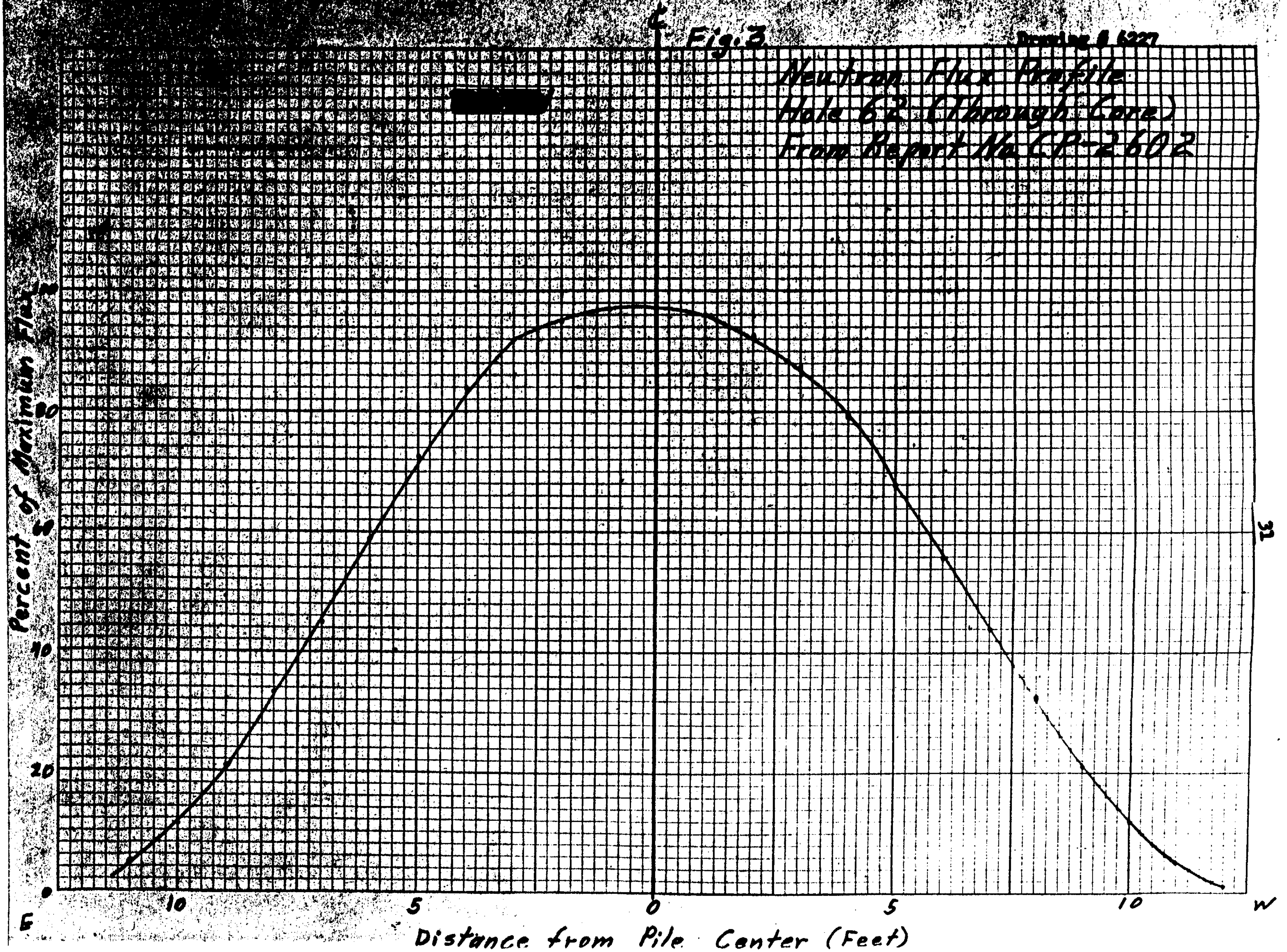
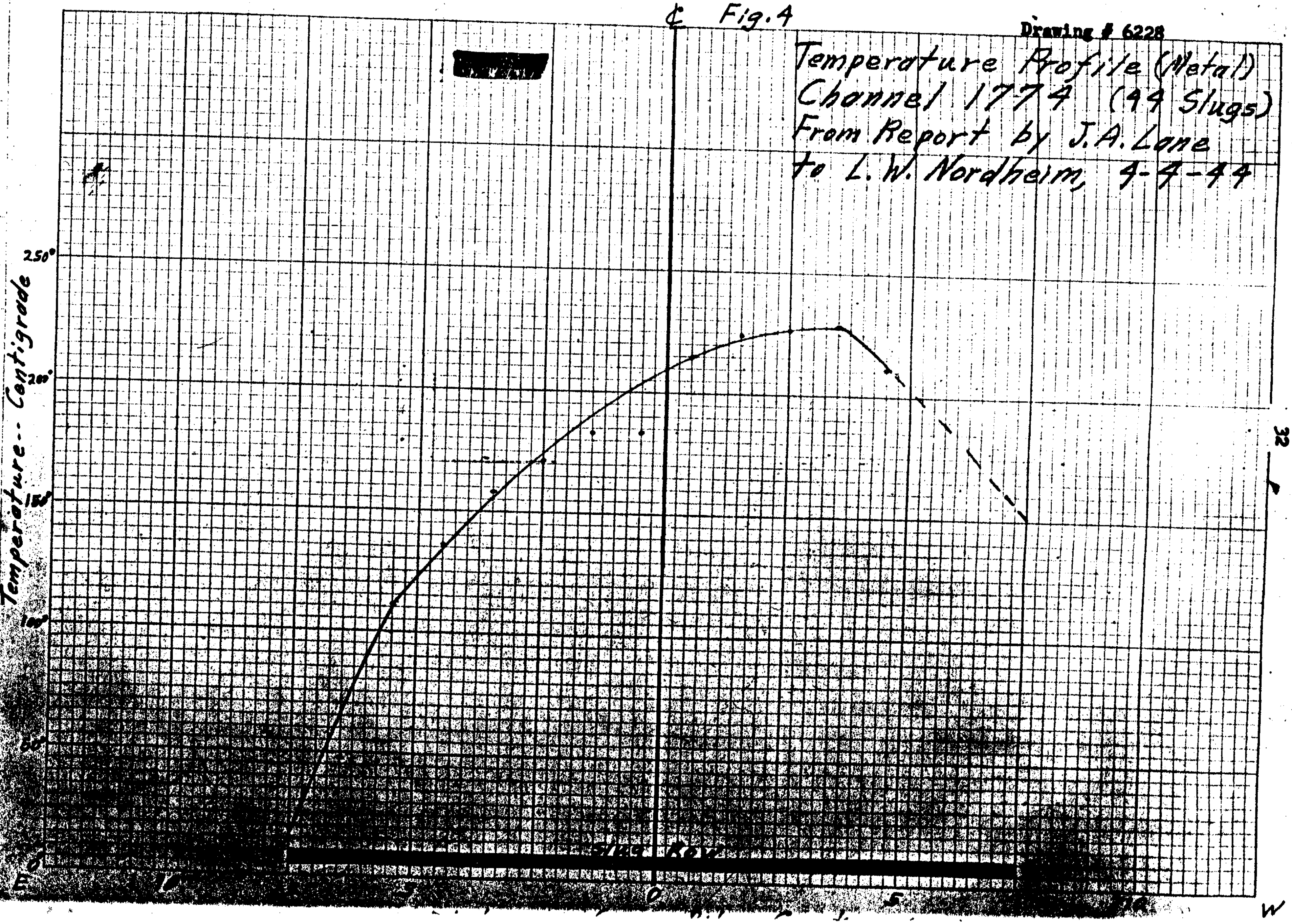


Fig. 3
Drawing # 6227
Neutron Flux Profile
Hole 62 (Through Core)
From Report No. CP-2602
Percent of Maximum Flux
20
40
60
80
0
10
5
0
5
10
E
W
Distance from Pile Center (Feet)

Drawing # 6228

[redacted]



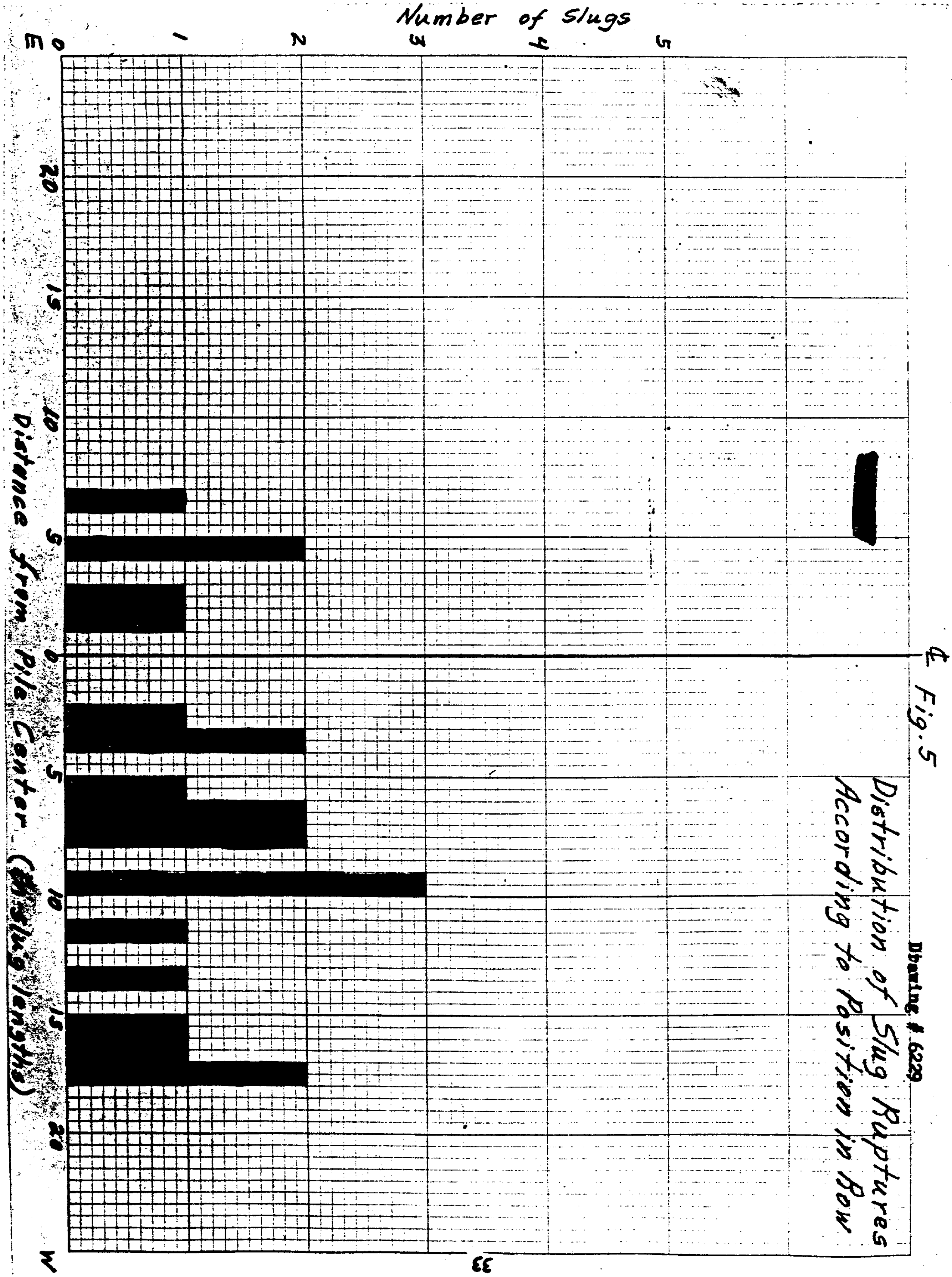


Fig. 5

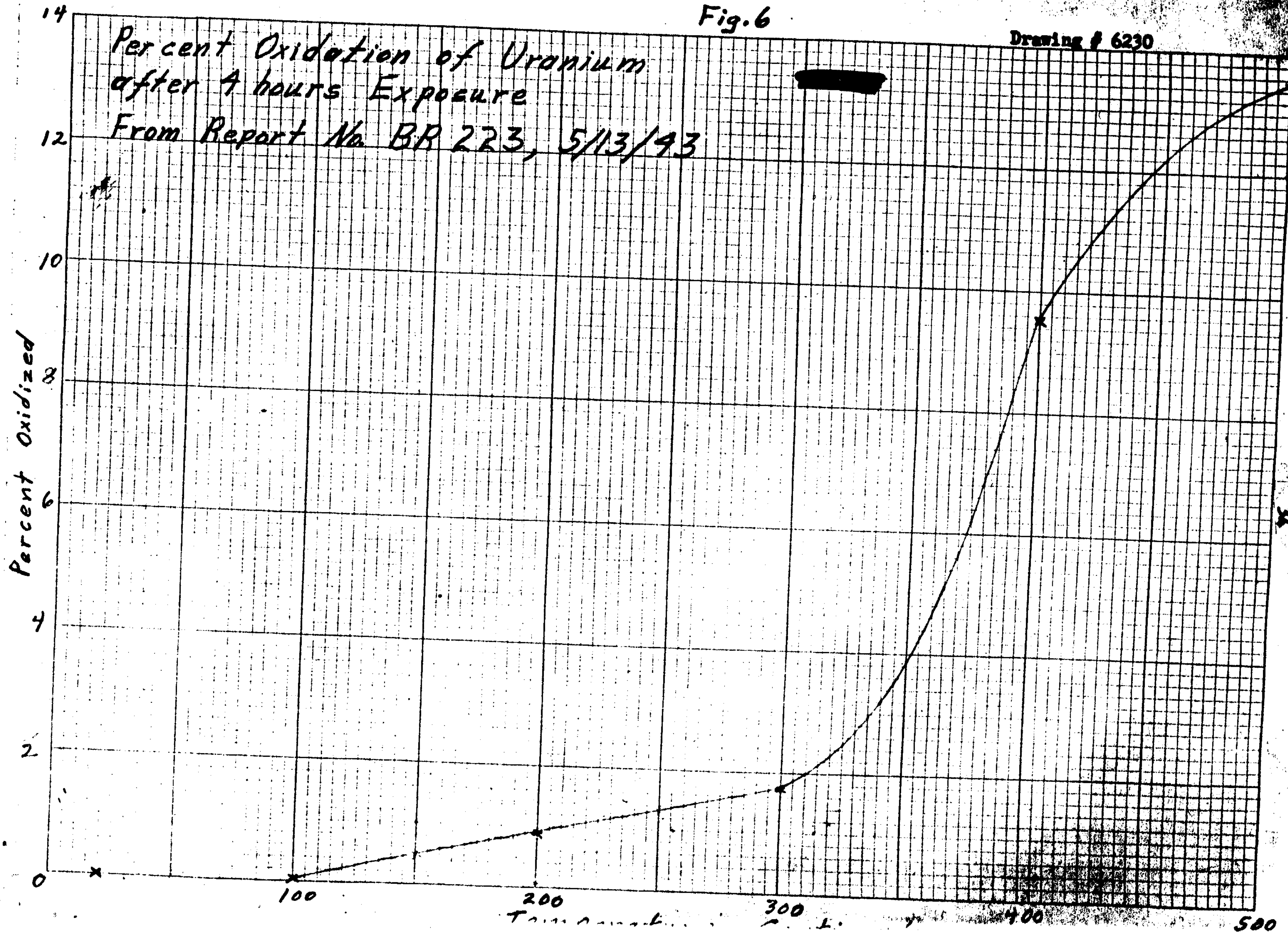
Distribution of Slug Ruptures According to Position in Row

Drawing # 6229

Fig. 6

Drawing # 6230

[redacted]



5231
Drawing #

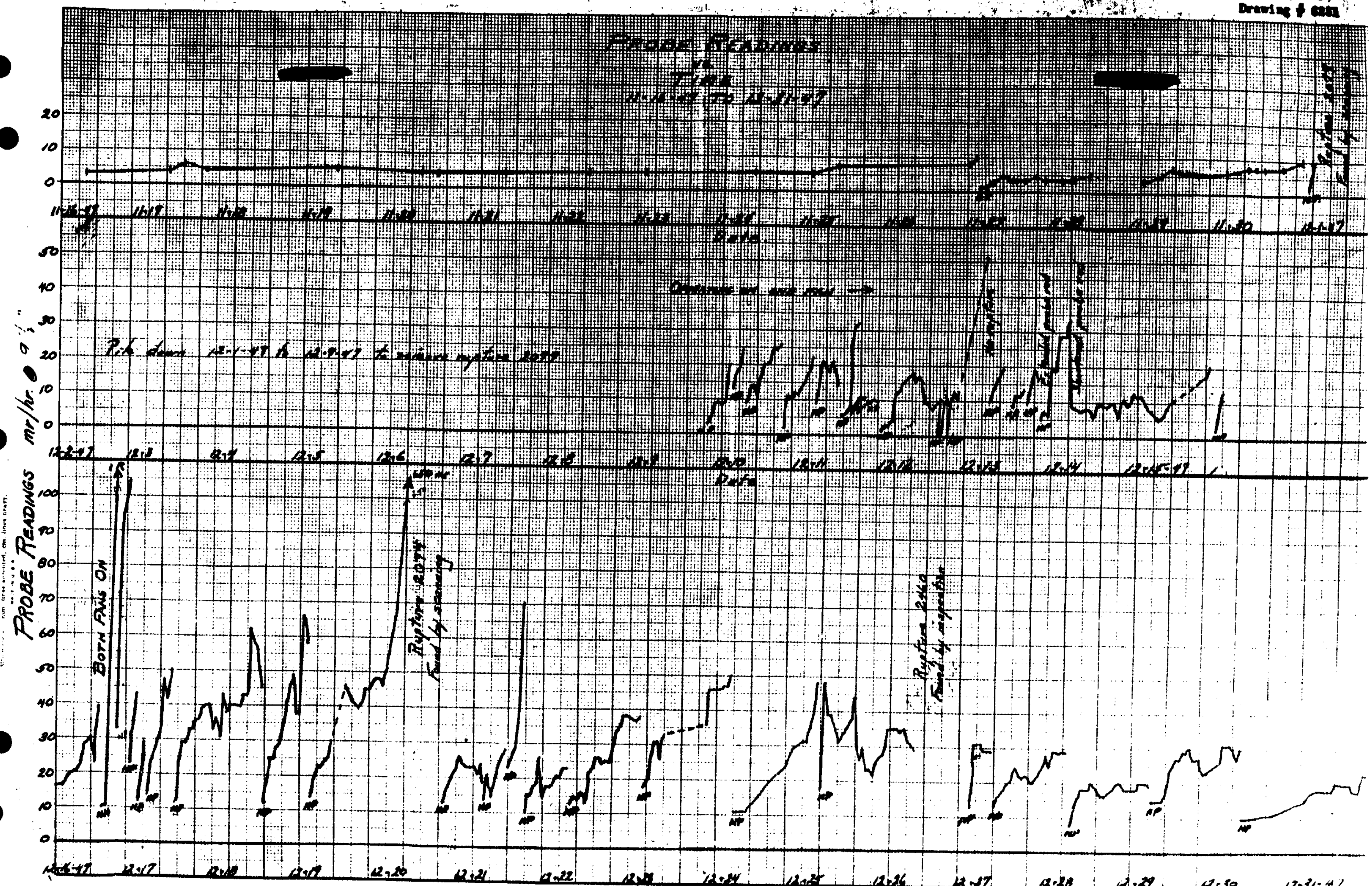
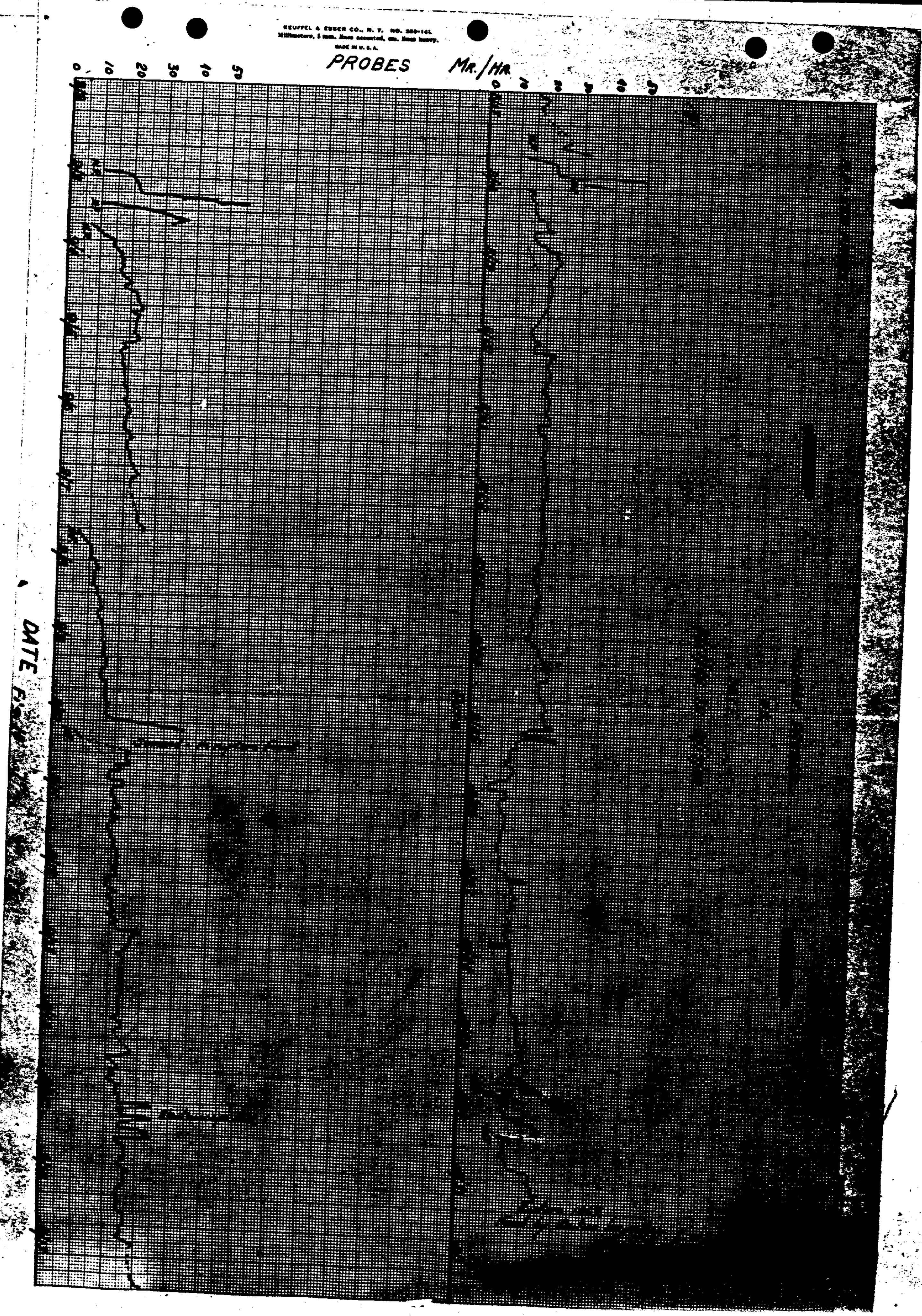
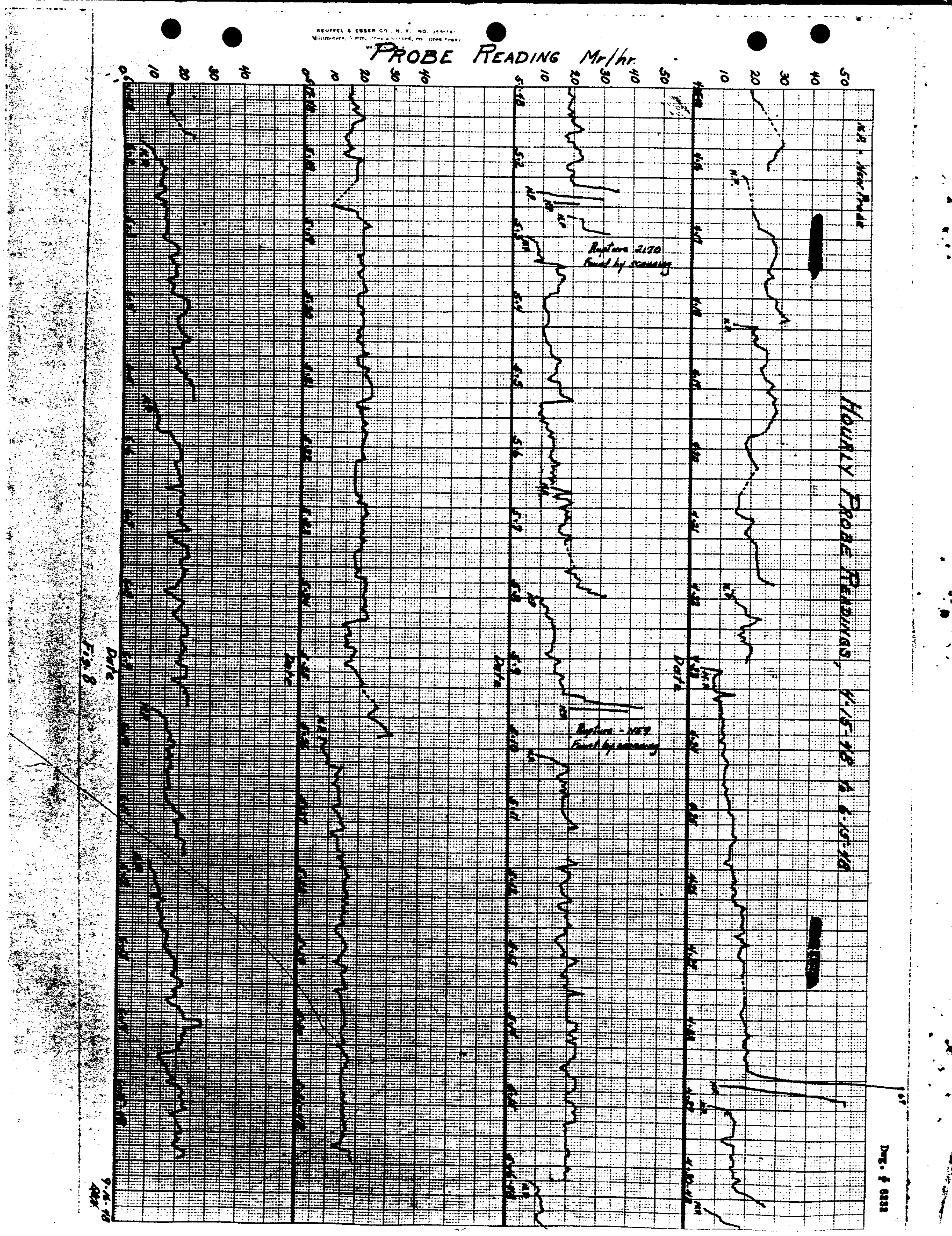


Fig. 7

9-20-48


KEUFFEL & ESSER CO., N.Y. NO. 359-14L
Millimeters, 5 mm. lines accented, cm. lines heavy.
MADE IN U.S.A.
PROBES
MR./HR.
0
10
20
30
40
50
DATE


PROBE READING Mr/hr.
HOURLY PROBE READINGS, 4/15-48 to 6-15-48
N.P. = New Probe
Rupture 2170
Found by scanning
Rupture - 1159
Found by scanning
Date
Fig. 8
Dwg. # 6882

Drawing # 6335

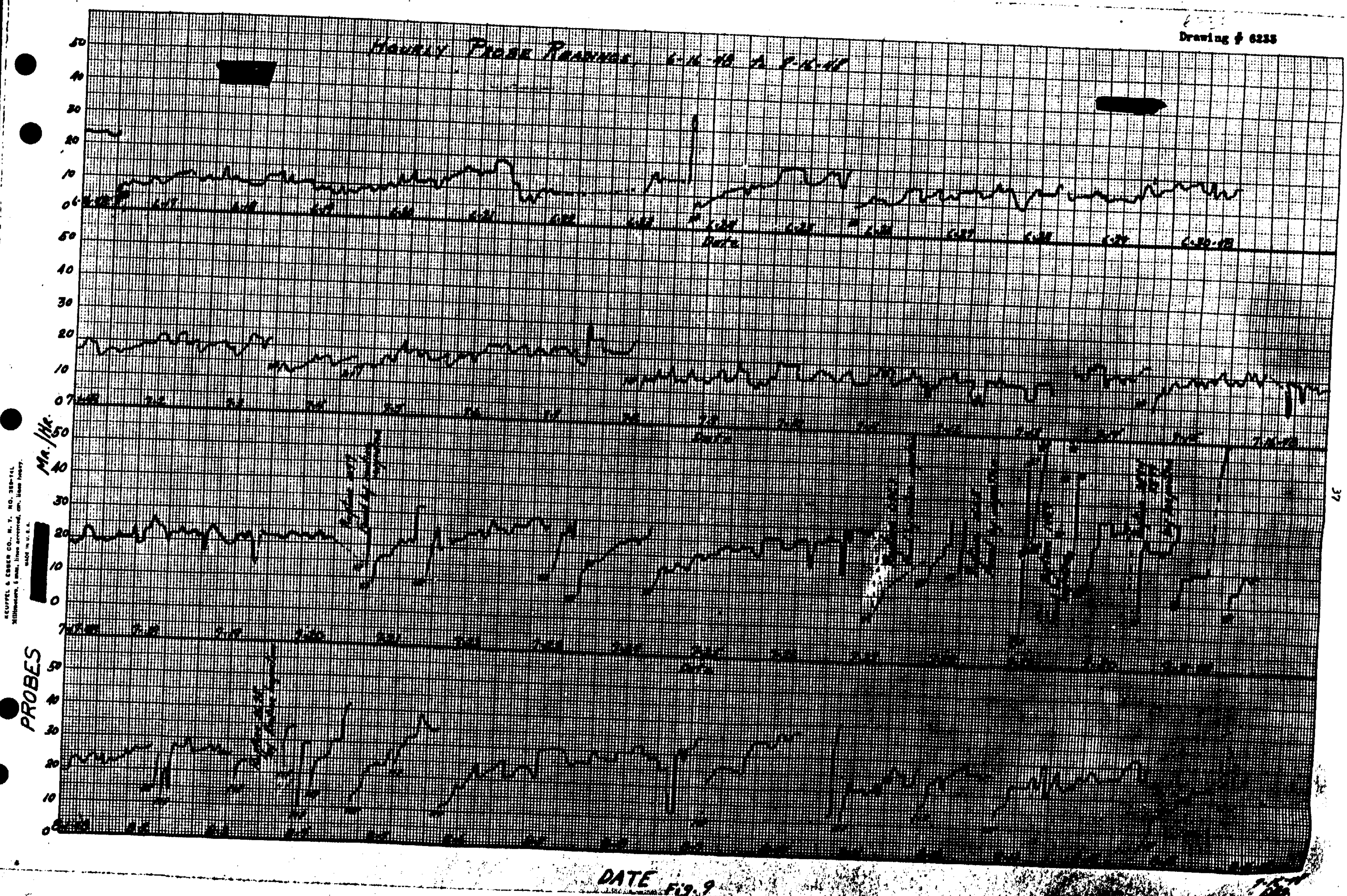


Fig. 9